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SOME ELLIPSOIDAL LAVAS ON PRINCE WILLIAM SOUND, ALASKA[1]

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Many descriptions of ellipsoidal, spheroidal, or pillow lavas have been published from time to time. Rocks of this type have a wide geographic range and have been formed at intervals from pre-Cambrian to the present. Various conclusions have been reached by different writers as to the mode of origin of ellipsoidal lavas, and the reasons for the development of their peculiar ellipsoidal, spheroidal, or pillow-shaped forms. The ellipsoids or pillows have been considered to be (1) concretionary, (2) the result of brecciation, (3) due to contraction, (4) accumulations of volcanic bombs, (5) the result of explosive eruptions, (6) and the result of submarine cooling. In a recent article N. Sundius[2] has well summarized the important literature on the subject.

Notwithstanding the various hypotheses which have been advanced to explain this phenomenon, it has come to be generally accepted that the ellipsoids are the result of the flowing of the lavas into water, or their extrusion under water, and are due to the rapid cooling of the flowing molten material under these conditions. Tempest Anderson[3] has described recent pillow lavas actually seen in the process of formation, and there now seems to be little reason to doubt that the chilling of lavas under water is responsible for many of the ellipsoidal lavas with which we have become familiar. The purpose of this paper is to present certain facts which seem to the writer to prove conclusively that the ellipsoidal lavas near Ellamar, Alaska, were subaqueous flows, and to give certain criteria which, in this field at least, proved of value in determining which was the upper and which the lower side of a given flow as deposited, thus aiding in deciphering the structure in a region where the normal attitude of the beds had in many places been obscured, and where overturning of the beds might be expected.

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[1] Published by permission of the Director, United States Geological Survey.

[2] N. Sundius, "Pillow-Lava from the Kiruna District," *Geol. fören. Förhandl.*, Bd. 34, Häft 3 (1912), pp. 317–33.

[3] Tempest Anderson, "The Volcano of Matavanu in Savii," *Quarterly Jour. Geol. Soc.*, XLVI, No. 264 (1910), 621–39.

The ellipsoidal greenstones here described were studied in the vicinity of Ellamar, Alaska, in the fall of 1912, during an investigation of the geology and mineral resources of the district by Mr. B. L. Johnson and the writer. The exact age of the greenstones is not known, but they are associated with a thick series of sedimentary beds which are believed to be for the most part of Mesozoic age. The greenstones were of especial interest because all of the copper deposits of the district are in the greenstone, or closely associated with it. In those areas in which the greenstones are most highly mineralized the lavas have been extensively sheared and meta-

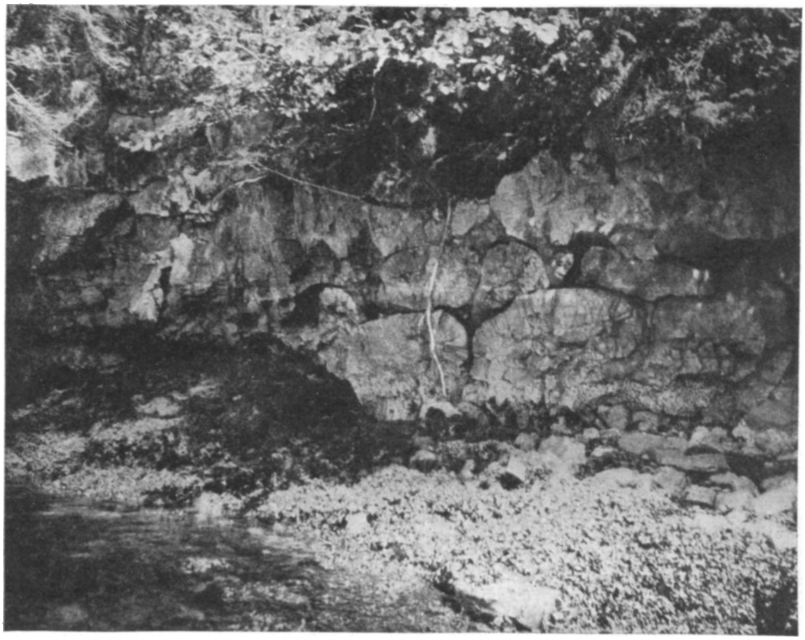

FIG. 1.—Cross-section of lava flow, showing ellipsoidal forms. The ellipsoids are characterized by both radial and concentric sets of cracks. Photo. by S. Paige.

morphosed, so that they have almost completely lost their original appearance. In other places, however, the lavas have been tilted, with only slight folding and with little shearing, so that their original character is well preserved. The term greenstones has been commonly applied to these rocks, which are all diabases or basalts. The writer prefers the term "ellipsoidal" to other commonly used terms such as "spheroidal" or "pillow" lavas, for the forms are most often ellipsoidal in cross-section (Fig. 1), but in plan they appear as more or less continuous bodies with irregular bulges and protuberances (Figs. 2 and 3).

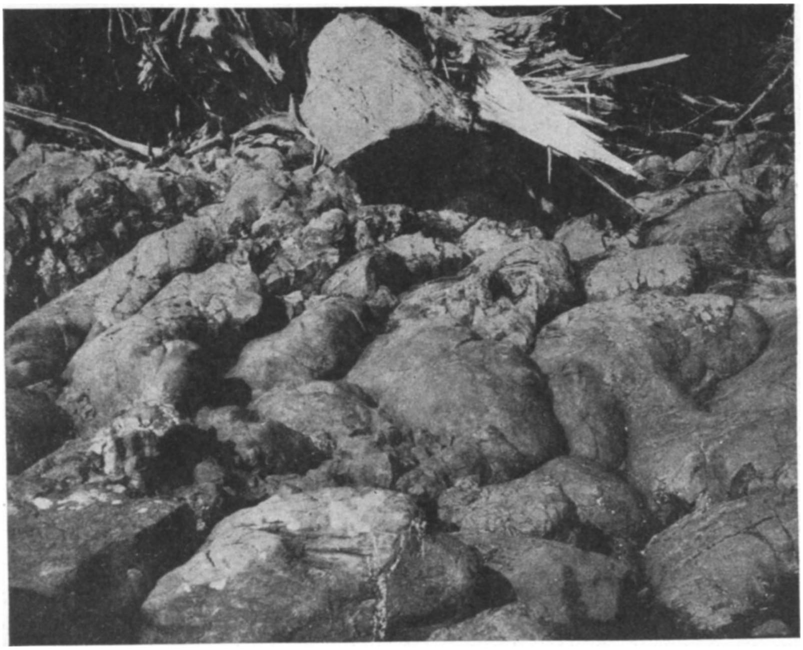

FIG. 2.—Uptilted ellipsoidal flows, showing irregular shapes of the flow forms. Photo. by B. L. Johnson.

The best exposures for studying the ellipsoidal lavas were found along the shore from two to four miles northwest of the village of Ellamar, toward Rocky Point. There the waves have cut steep sea cliffs which rise from the water's edge, often with no beach at all, and the exposures are fresh and perfectly free from covering.

An examination of this section shows that although the ellipsoidal flows form the larger proportion of the series, they are interbedded with some more massive diabase beds. At intervals, however, the extrusive rocks are seen to be interrupted by slates and graywackes, the sedimentary beds becoming thicker and more frequent as the top of the greenstone series is approached. The strike and dip of adjoining lavas and sediments is the same, and it is evident that clastic sediments were deposited at intervals between the outpouring of the lava flows (Fig. 4). In a large number of observations on slate or slate-graywacke beds interbedded with ellipsoidal greenstones, no single case was found in which there was a discordance in bedding between the sediments and the lavas. Furthermore, in the cracks between the ellipsoids of the lower part of a flow and in the smaller cooling cracks within the individual ellipsoids there were frequently seen thin vein-like layers of a black, shaly material which proved to be of the same character as the under-

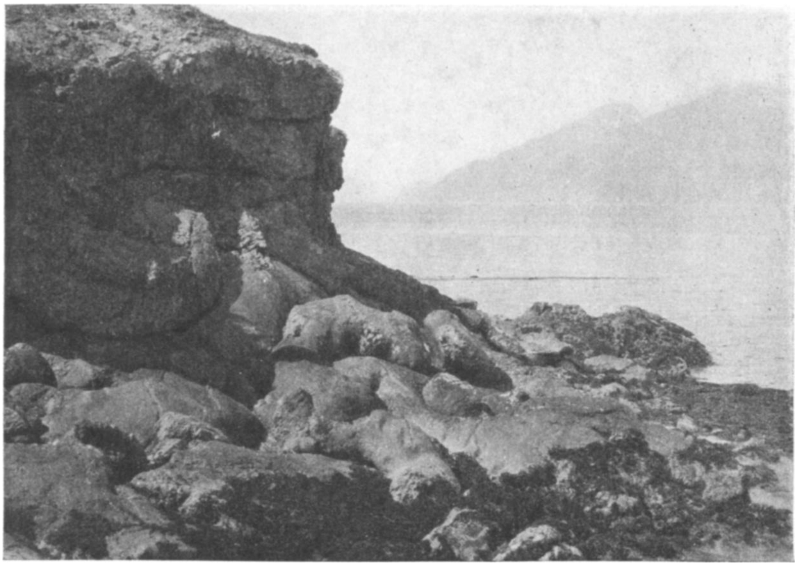

FIG. 3.—Ellipsoidal lavas. The forms are ellipsoidal in cross-section, but in plan are long uneven bodies characterized by bulbous portions separated by constrictions. Photo. by S. Paige.

lying sediments. The presence of this sedimentary material in the cracks of the fractured ellipsoids can be satisfactorily explained only by assuming that the bed of mud upon which the lava was extruded was at that time soft and plastic, and that upon the cooling of the lavas, and their cracking from shrinkage as they chilled, the weight of the lava bed forced the soft mud from below up into the cracks of the lava as fast as they were opened. In places these mud-filled cracks extend several feet into the flow, and where best developed give the rock a mosaic appearance, the fragments of greenstone, often only a few inches in diameter, being surrounded by a black layer of baked shale. The mud fillings of the cracks vary in width from the thickness of a knife blade to several inches. At one locality the openings between the ellipsoids were found to be filled with limestone.

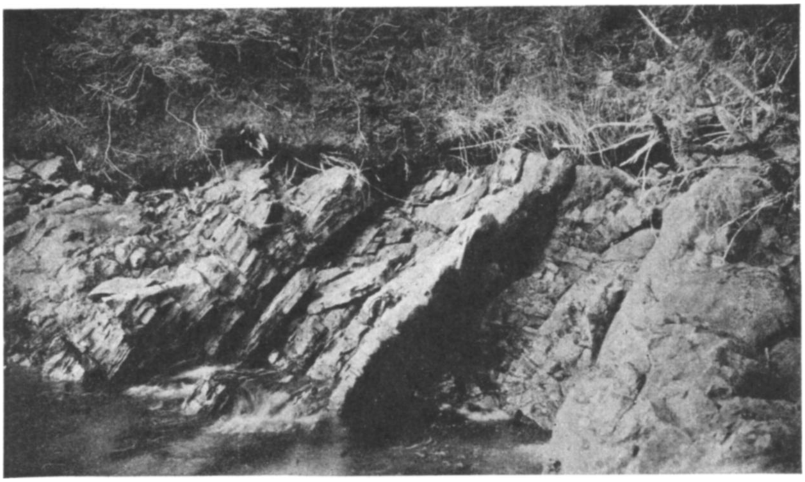

FIG. 4.—Steeply dipping ellipsoidal lava, on right, succeeded by conglomerate and graywacke. The uneven lower surface of the conglomerate conforms to the top of the underlying lava flow.

In those places where thin ellipsoidal greenstone beds were adjoined both above and below by sedimentary beds, it was found that the two surfaces of the flow presented different appearances (Figs. 4 and 5). The under surface in each case was flat, the ellipsoids of the lower layer being flattened at the base, though presenting curved surfaces on their other sides. At one place a steep overhanging sea cliff 30 feet high was formed by the base of such a flow, the underlying slate having been cut away. The base of this flow was flat and smooth, though the flow, as seen in section, was composed altogether of ellipsoidal lavas. Into the cracks in the base of this flow the mud had penetrated deeply. It is believed that the flat lower surface of this ellipsoidal flow could have been formed only by lava which was poured out upon a flat bed of sediments, the lava having conformed to the surface upon which it was deposited. The upper surface of an ellipsoidal bed presents a different appearance (Figs. 4 and 5). There the flow surface was under the pressure only of the column of water above it, and the surface hardened to form an irregular floor consisting of a succession of domes, like the surface of a magnified cobblestone pavement, the surface of the ellipsoids representing the cobble-

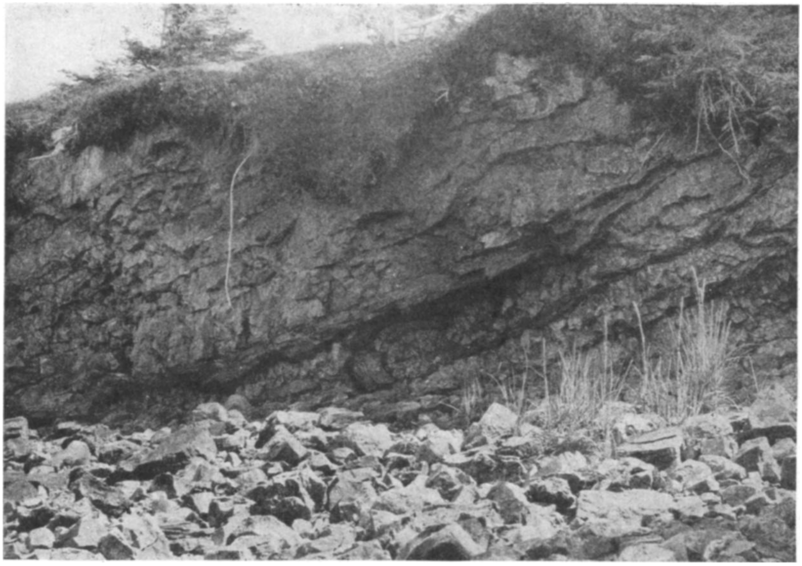

FIG. 5.—Ellipsoidal lavas below, separated from more massive diabase above by an intercalated shale bed. The lower surface of the shale is uneven, having taken the shape of the ellipsoidal lava surface upon which it was deposited. The overlying flow is flat on the bottom, conforming to the shale surface. Photo. by S. Paige.

stones. Upon this surface later deposits of mud were laid down, the bottom of the mud bed taking the shape of the irregular lava surface. The lava flows show no signs of weathering or erosion upon their surface, and the succeeding mud beds must have been laid down soon after the lavas cooled.

Summary.—The greenstones near Ellamar, Alaska, comprise a thick series of lava flows, most of the flows consisting of ellipsoidal lavas, and many of them displaying this character in a striking way. At frequently recurring intervals in the greenstone series there are interbeded slates and graywackes, and rarely some limestone, the sedimentary beds being in every case structurally conformable with the overlying and underlying lavas. The surfaces of the flows show no evidence of erosion or weathering, the succeeding sediments having been laid down upon the fresh, unaltered lava surface. If the greenstones are subaqueous flows, as is believed to be the case, then they were merely interruptions during the deposition of ordinary clastic sediments.

If, on the other hand, the lavas were not subaqueous flows, and were extruded upon land, it is necessary to postulate an elevation of the surface above sea level for each extrusion of lava and an immediate resubmergence for the deposition of the sedimentary beds. In view of the many recurring sedimentary beds throughout the greenstone series, this latter assumption seems most unlikely. The absence of evidence of erosion or weathering on the surface of the lava flows also supports the conclusion that they solidified below sea level, as does the presence in the lava cracks of thin films of mud which must have been plastic at the time they were injected.

The difference in appearance of the flat bottom of an ellipsoidal flow, with its abundance of mud-filled cracks, from the uneven upper surface of the same flow, and the consequent unevenness of the bottom of the succeeding sedimentary bed often made it possible to determine which surface of a steeply tilted bed was originally the upper surface, and was a valuable aid in working out the structure of the beds.